programs, such as SRiM, while others offer collaborative opportunities throughout the year.

- *Read the application guidelines carefully.* Due to funding sources, many programs require someone in the research group to be a citizen or permanent resident of the home country. Read all the rules carefully and decide if your group meets the criteria. Keep in mind the project requirements. Some programs require you to have partial results and some do not. The SRiM program is indeed one for which your group is expected to have made progress towards your project goals at the time of applying.
- *Ask around.* Often the program's website will show recent recipients of the grant whom you might contact for any advice, or even to receive a copy of their successful application. It helps to know someone, but people are often friendly and want to help others succeed.
- *Sell yourselves!* Make sure to highlight your expertise and your contributions to the field(s) germane to your proposal. As mentioned above, the SRiM program privileges project proposals for which the group has already made progress; be sure to highlight any partial results your group has achieved.
- *Keep working.* While you are waiting, you need to keep working with your collaborators online as you never know if your group will get the grant or not. Even if you do get the grant, the proposed time of your visit may not work for your entire group, or the funding could be insufficient for those with little support from their institutions.
- *Be communicative.* If your group decides to turn down an offer, be sure to let the institute know early so they can give the opportunity to another group. In 2019, we were second-round awardees. Because those first-round recipients communicated early to MSRI that they were passing on their offer, we were able to plan early (which is so important with small children). On the flip side, if you have not heard by the decision date listed on the program's website, do not hesitate to contact that program to see what the status of your proposal is. Keep checking in, letting them know your group is still interested.

Again, to our knowledge, the SRiM program at MSRI offers the most support for researchers with children as compared to other institutes. The first author had also been a part of another research group that had been accepted to more than one institute's collaboration program. Because of the excellent family support that SRiM offers, that group took MSRI's offer.

If your group does not get a grant, do not be disappointed as you never know what could happen. As mentioned above, our group was a second-round awardee.

Regardless, we have all learned how to live virtually (for better or worse). Take advantage of those new skills to keep working together, even if just a short weekly check-in to see how you all are doing; you can always apply again next year. Good luck!

Kuei-Nuan Lin   Augustine O'Keefe

Credits

Photo of Kuei-Nuan Lin is courtesy of Kuei-Nuan Lin.
Photo of Augustine O'Keefe is courtesy of Augustine O'Keefe.

IMA Math-to-Industry Boot Camp

Fadil Santosa and Daniel Spirn

The IMA Math-to-Industry Boot Camp is an intensive six-week summer training program that prepares mathematics PhD students for internships and careers outside of academia. Though the program has its roots in industrial modeling workshops, this program was specifically developed to help address two demographic challenges to the mathematics community: (1) an overabundance of mathematics PhDs in relation to the number of permanent academic positions and (2) the growing need for mathematically sophisticated scientists in industry and government workplaces. Since 2016, the Boot Camp has trained well over 200 math and statistics PhDs students with very promising results.

Over the past several decades there has been a large increase in the number of students pursuing degrees in mathematics at the graduate level. And while the number of mathematics students finishing with PhDs has been increasing, the percentage of traditional tenure-track and tenured positions has decreased precipitously nationwide. For example the percentage of tenured faculty in US higher education across all subjects has dropped 20% between

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1995 and 2019 [DBSZD21]. At the same time the Bureau of Labor Statistics has estimated that the number of jobs in the mathematical sciences will increase 33% between 2019–2029 [BoLS21]. While some students are ready to pivot towards industry jobs, many do not know how, and their departments do not provide programs to lead the way.

Origins of the Program

The IMA Math-to-Industry Boot Camp, funded initially in 2016 by a three-year NSF Enhanced Doctoral Training grant (DMS-1551205), was pitched as a pathway for near terminal graduate students in pure mathematics to quickly retool for a job in industry. Though initially targeted towards mathematics students with little background in programming and modeling, the program is open to PhD students from US institutions in any subject in the mathematical sciences and at any point prior to graduation. One key feature of the camp is the opportunity to participate in an industry-sponsored team project under the supervision of an industrial scientist. This team project is based on the format of the IMA Math Modeling workshops, which ran from 1996 until 2015. IMA Math Modeling workshops were developed for and targeted towards PhD students in applied and computational mathematics with two goals: providing students the chance to learn about mathematical challenges in industry and offering industrial scientists the opportunity to learn about cutting-edge methods being developed in academia. On the other hand, the goal of the IMA Math-to-Industry Boot Camp is to prepare any mathematics PhD student to potentially pivot away from an academic career.

Boot Camp Program

Roughly thirty math graduate students are selected from all facets of mathematics, including subjects quite far from the traditional view of industrial or applied math. These students spend the first three weeks immersed in mini-courses on the basics of programming, data exploration and modeling, machine learning, stochastic modeling and optimization techniques. The aim of each of these programs is to quickly gain comfort with coding and prototyping in R, Python, and Gurobi. During these first few weeks, trained specialists lead sessions on developing professional skills including team dynamics, conflict resolution, and presenting research to non-technical decision makers. Throughout the six-week program, students interact with visiting industry professionals via presentations and informal discussions.

During the second three weeks of the Boot Camp, students are challenged with team projects that originate from industrial research centers and national labs. Each team is mentored by a scientist (or scientists) from the sponsoring company. Projects are typically drawn from a core business, and these problems are brought to the camp as a potentially important direction of exploration that the mentor can

present to her/his team. These industry-sponsored projects provide the chance for the students to practice their new-found technical and professional skills.

Projects are drawn from broad sectors of industry and government. For example, the 2018 projects were sponsored by National Securities Technologies (defense), D-Wave systems (quantum computing), 3M (industrial products), Schlumberger-Doll (geoscience), Whitebox Advisors (finance), and the Milwaukee Brewers (entertainment).

Outcomes

The benefits of the Math-to-Industry Boot Camp are manyfold. To students the program provides several special opportunities that may not be experienced in a typical mathematics graduate program:

- The chance to interact with mathematicians working in industry and national labs.
- The opportunity to quickly develop comfort and skills with working with a team on open-ended applied research projects with short deadlines.
- An experience that will help them qualify for industry jobs where recruiters are looking for scientists who have had experience working with a company-sponsored project.

Perhaps, more than anything, the program gave these students confidence that they can land a job and thrive in industry.

Likewise companies have also found value in mentoring a Boot Camp project, including as a way to explore new directions of research, an opportunity to recruit from a diverse group of students, and as a chance for early-career industrial scientists to gain experience running a small team.

The pre- and post-assessments have demonstrated successful outcomes for both participants and mentors. In particular, students and mentors reported that students had built valuable skills and learned what a career in industry might be like. This was seen as particularly valuable for the individual mentors as well as their companies. Mentors and students also talked about how this intensive experience with a cohort would help to build additional bridges of knowledge and personal relationships between industry and academic mathematicians, bridges that all saw as valuable and mutually beneficial for ongoing research and problem solving in both sectors.

The IMA has also documented individual success stories. Keith Rush is just such an example. While a graduate student at the University of Wisconsin Madison studying orthogonal polynomials, he participated in the 2016 Boot Camp. When he interviewed that fall, he described his Boot Camp experience and was offered a job with the Milwaukee Brewers as the first member of a new data science team charged with improving ticket sales. Buoyed by this success, the Brewers hired a second IMA Boot Camp participant, Michael Dairyko (Iowa State PhD in combinatorics, 2017 Boot Camp). During the 2018 Boot Camp, Keith Rush

returned as a project mentor where his team worked on sequence-to-sequence modeling.

Alumni of the Boot Camp have taken positions throughout all sectors of BIG (Business, Industry, and Government). In government, we have alumni in the Federal Reserve, the FDA, Pacific Northwest National Lab, and Sandia National Lab. In retail, our students have found jobs at Amazon, Sam's Club, and Target. Several went to "big tech" such as Google, eBay, and Microsoft. Other companies employing our alumni include JP Morgan, Lockheed Martin, Astra Zeneca, among many, many others.

Pivoting to Online

Rather than cancelling the Boot Camp during the COVID-19 crisis, the IMA decided to run the summer 2020 Boot Camp virtually, albeit with several modifications. As all instruction transitioned online, so too did the Boot Camp minicourses. However, the most critical part of the camp experience, working on an industry-sponsored team project, was a cause of concern. We especially wanted students to experience the pitfalls and challenges as well as the exhilaration of quick discovery and prototyping. In order to encourage team building and collaborative communication, the IMA experimented with software platforms and arrived at a suitable framework:

- Instruction, skills development, and cohort meetings worked exceptionally well on Zoom, which also allowed for archiving of lectures and course material.
- Frequent check-ins with the full cohort proved to be an excellent way to build rapport among students.
- Project teams messaged and provided running updates on Slack. Git repositories were used to collaborate on data manipulation and software development.
- Online team presentations, provided at several stages during the last three weeks, worked very well. Zoom allowed for seamless handoffs between team members with easy integration of slides.

The results proved so promising that six months later, the IMA held an inaugural two-week winter Boot Camp in January 2021. Instead of offering a three-week instruction period during the camp followed by team projects, students were asked to prep for the courses with recorded lectures and tutorials. Though the January 2021 cohort skewed more towards applied mathematics, many of the students started with little to no experience in programming and data science.

Conclusion

Programs like the IMA Math-to-Industry Boot Camp provide a framework for training a broad array of math PhD students for employment outside of academia. Many of the lessons learned could be applied in departments offering PhD degrees in the mathematical sciences. A program similar to the one offered at the IMA can be created either by a department, or better still, by a consortium of several geographically nearby departments. The consortium model allows for sharing of resources and having a critical mass of students. We hope such programs will provide PhD graduate students across the country the opportunity to prepare quickly for mathematics jobs outside of academia.

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Fadil Santosa   Daniel Spirn

Credits

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Pset Partners

Andrew V. Sutherland

Introduction

The brutal murder of George Floyd last year and the protests that followed sparked some difficult discussions within our department, and some serious introspection. Some of the ways in which structural racism and inequity impact the mathematical community are obvious, most notably in the lack of diversity in our ranks. But some can be less obvious, especially to those not directly impacted by them.

One issue that has been particularly challenging for us at MIT is inclusivity. Reading over some of the discussions from last year I am still struck by the opening lines of "A Message to the MIT Math Community," an anonymous post to our discussion forum for mathematics majors that was

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